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EXCELENCIA SEVERO OCHOA

CALIOPE-urban: coupling R-LINE with CMAQ for urban air quality forecasts over Barcelona

UNC INSTITUTE FOR THE ENVIRONMENT

Jaime Benavides in collaboration with Michelle Snyder

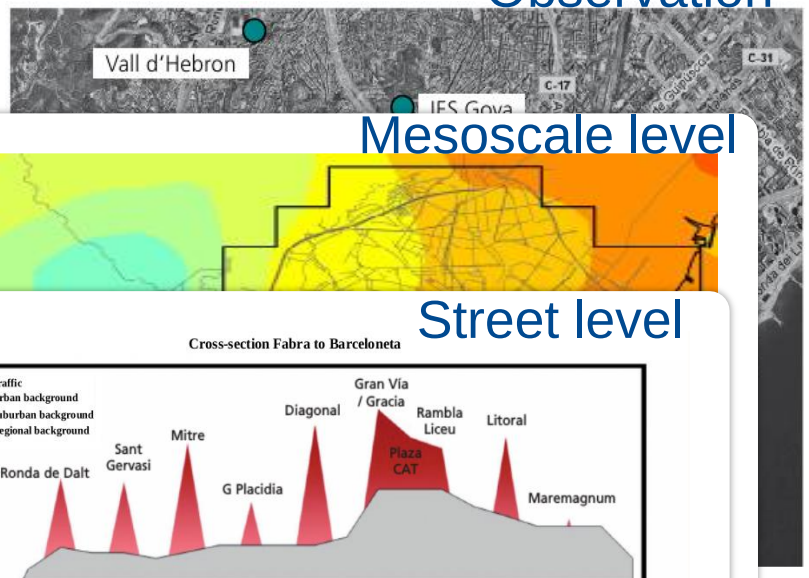
Supervisors: Albert Soret, Marc Guevara and Oriol Jorba

Modelling street scale air quality

Abstraction Level

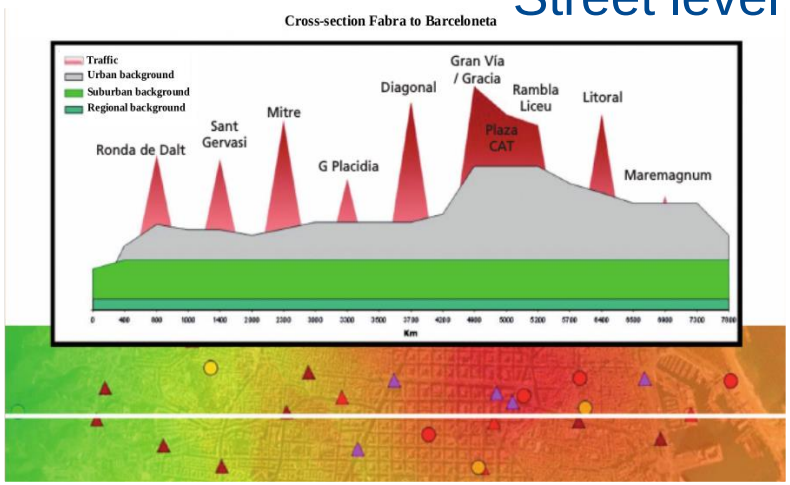
Reality

Observation

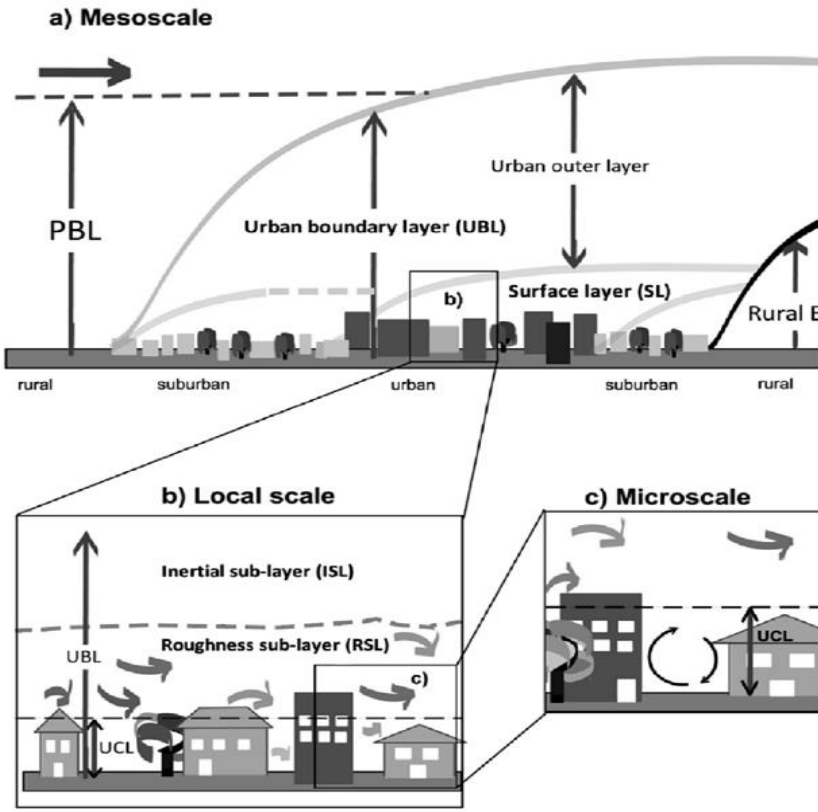


Mesoscale level

Street level

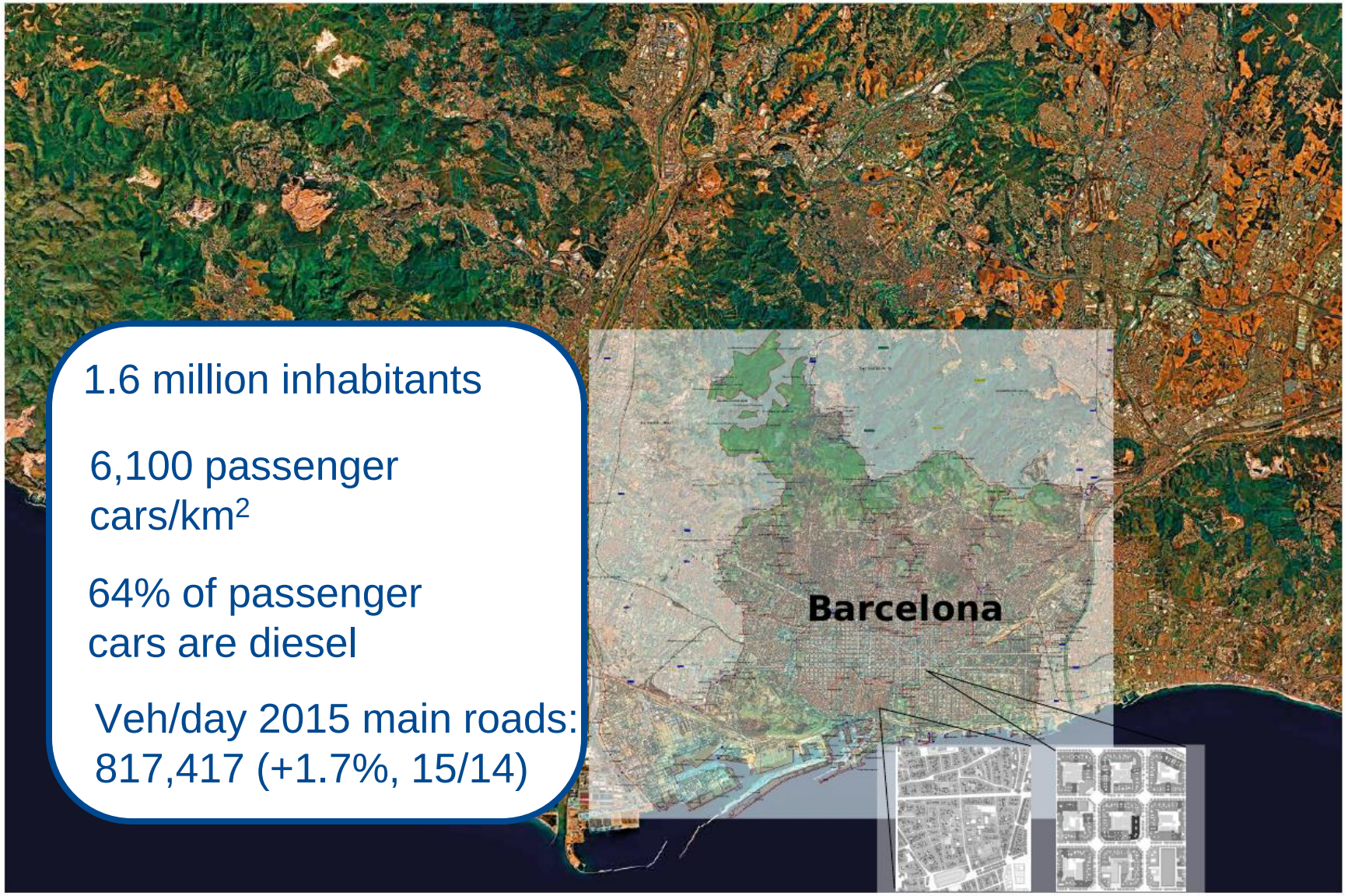


Querol et al. (2012).



Lateb et al. (2016)

Area of study: Barcelona



NO2 levels in Barcelona (2000-2016)

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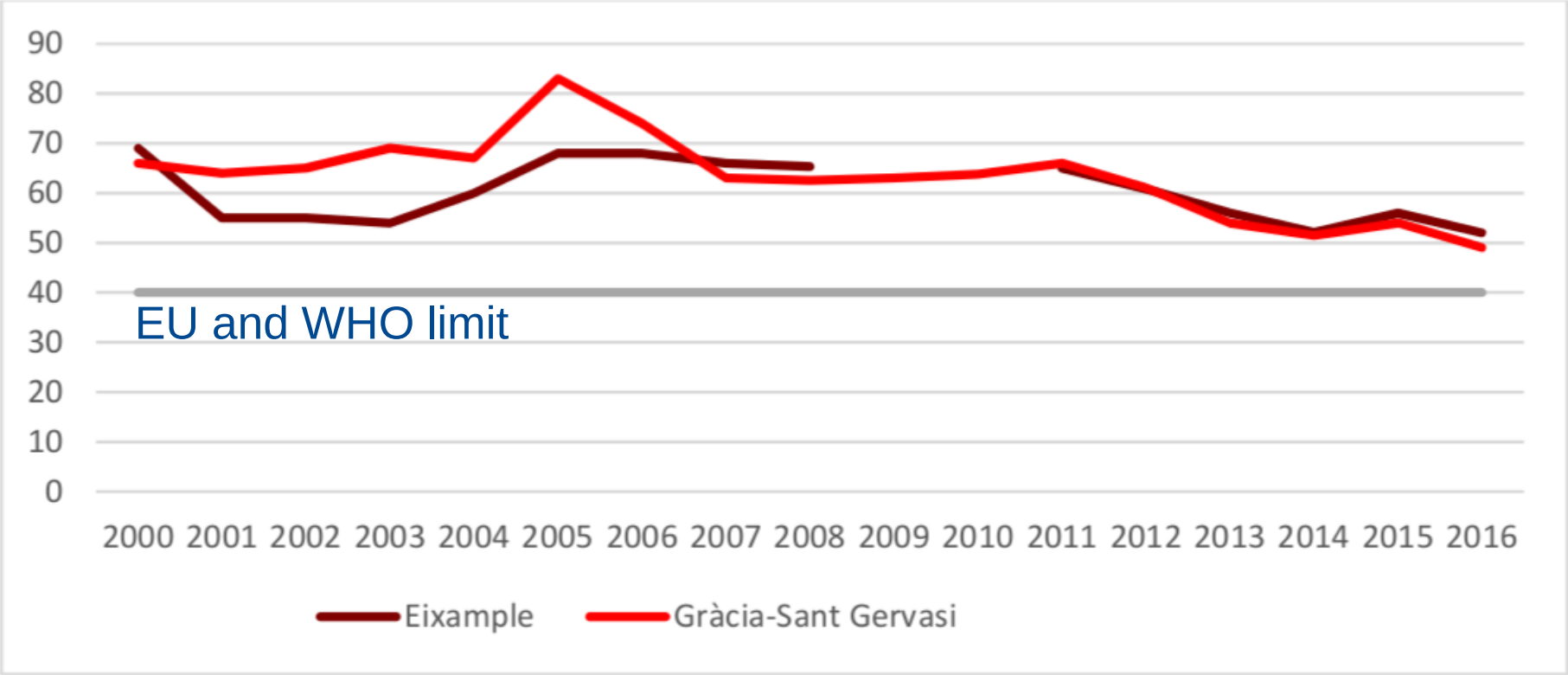
NO2 annual mean variation at traffic stations in µg/m3



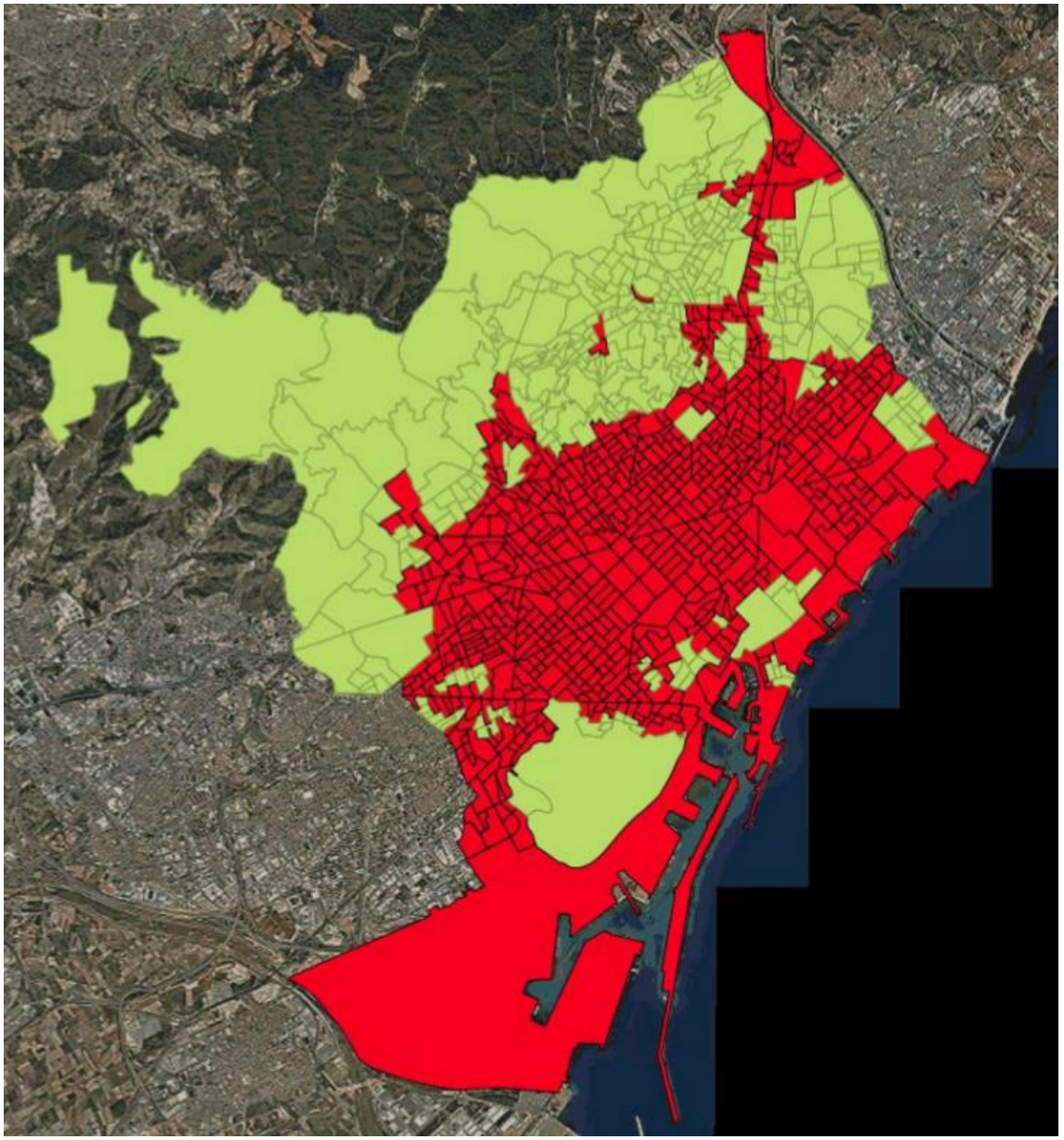
Agència de Salut Pública de Barcelona (ASPB, 2017)

Exposure to NO_2 levels in Barcelona in 2016

68% population exposed to > 40 µg/m3 annual mean in 2016

ASPB (2017)

Street level predictions are needed to inform citizens



CALIOPE: Air Quality Forecasting System

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CALIOPE Modules

Meteorology
- WRF-ARWv3.5
- 38 sigma levels (top 50 hPa)
- IBC: GFS (NCEP)

Emissions
- HERMESv2
  - EU: HERMES-DIS (EMEP data)
  - Spain: HERMES-BOUP

Chemistry
- CMAQv5.0.1
- CB05/AERO5
- BC: NCAR MOZART4
- 15 layers/ 50 hPa

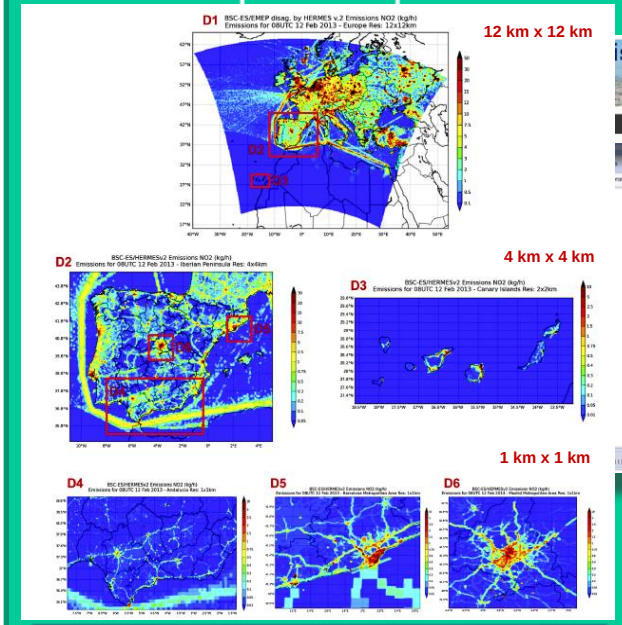
Mineral Dust
- BSC-DREAM8bv2
- PM10 and PM2.5

Post-process
- Kalman Filter (1D and 2D)

Air quality forecast

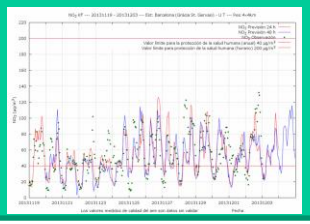
Forecast 48h

- Maps (AQ concentration, emis, meteo)
- AQ index / Population exposed



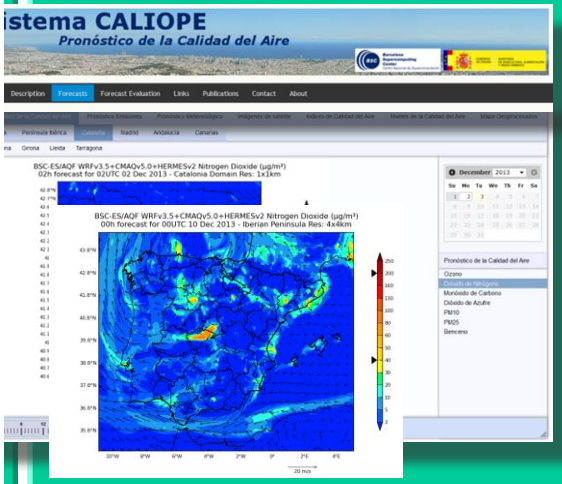
Forecast Evaluation (NRT)

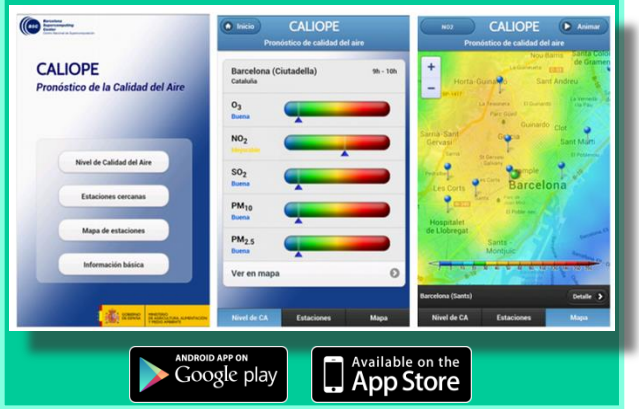
- AQ monitoring network
- Satellite



Difusion

- Web (www.bsc.es/caliope)
- Smart phone app





ANDROID APP ON Google play
Available on the App Store

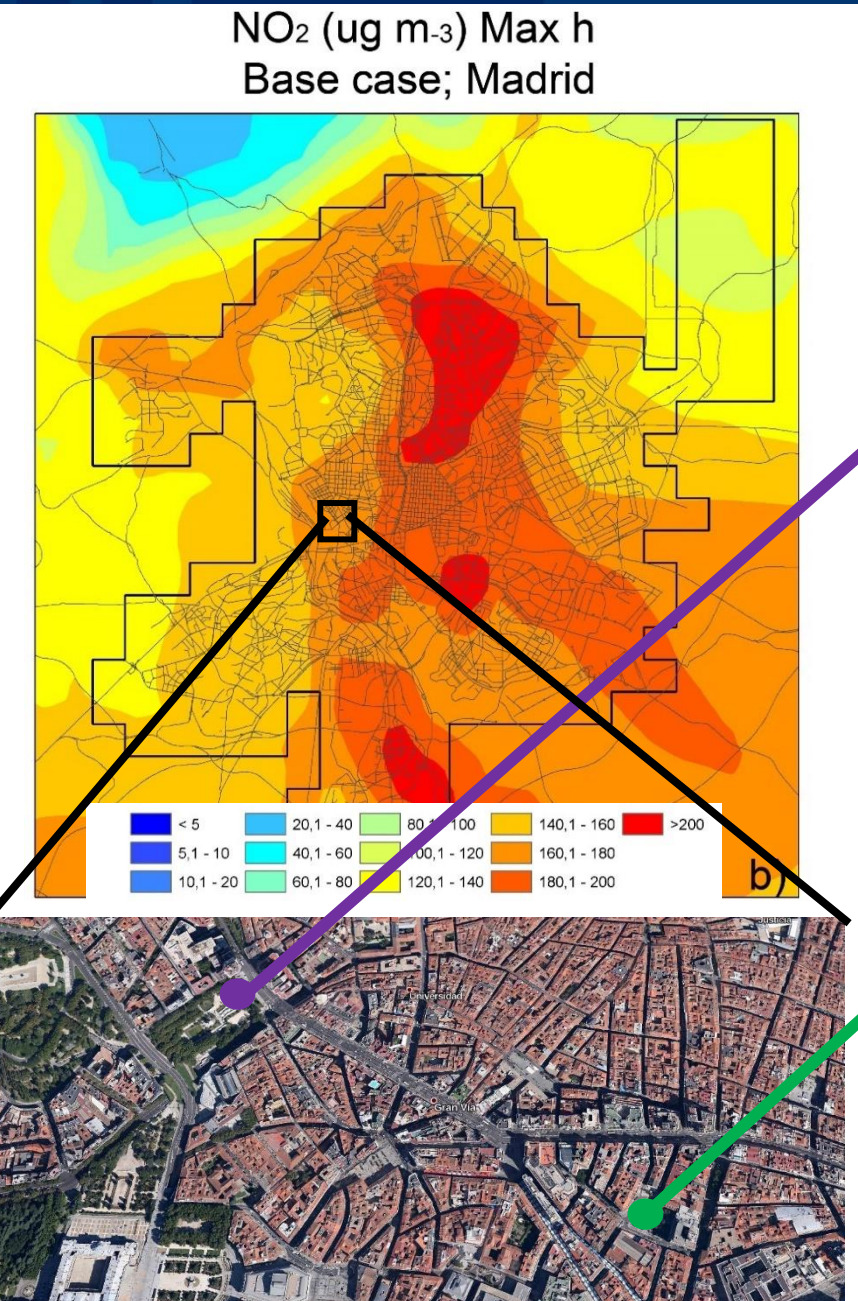
Generalitat de Catalunya
Departament de Territori i Sostenibilitat

GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

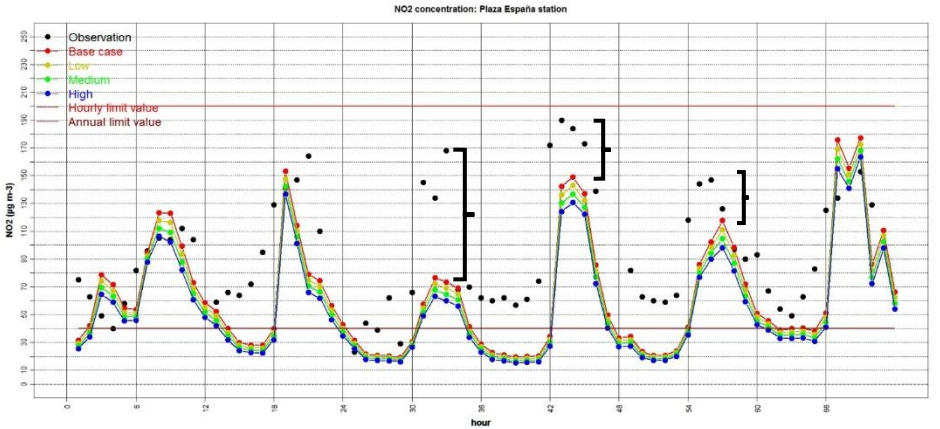
Gobierno de Canarias
un solo pueblo
Consejería de Educación, Universidades y Sostenibilidad

JUNTA DE ANDALUCIA
CONSEJERÍA DE MEDIO AMBIENTE Y ORDENACIÓN DEL TERRITORIO

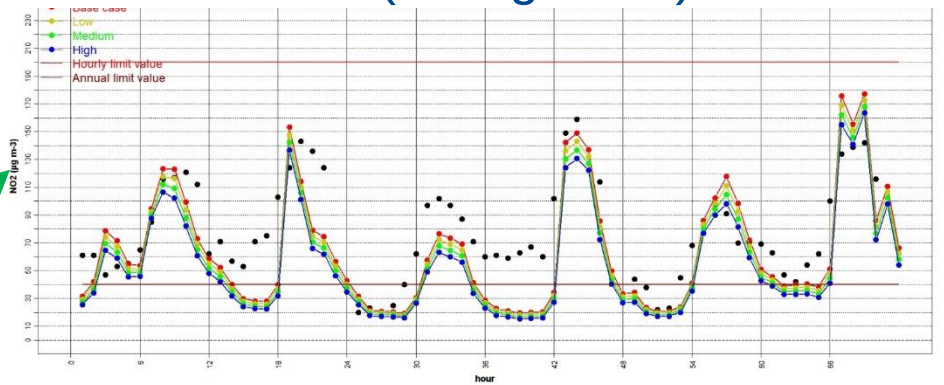
Problem definition



NO_2 hourly concentration. Plaza de España station (traffic)



NO_2 hourly concentration. Plaza del Carmen station (background)



Soret et al. (2014)

Objective and research questions

Main objective:

- To estimate NO_2 concentrations at street level in Barcelona using a combination of CALIOPE-AQFS with a street scale air quality model.

Research questions:

1. What street scale model should be used to estimate NO_2 concentrations at street level over Barcelona?

2. How should the street scale model be combined with CALIOPE-AQFS?

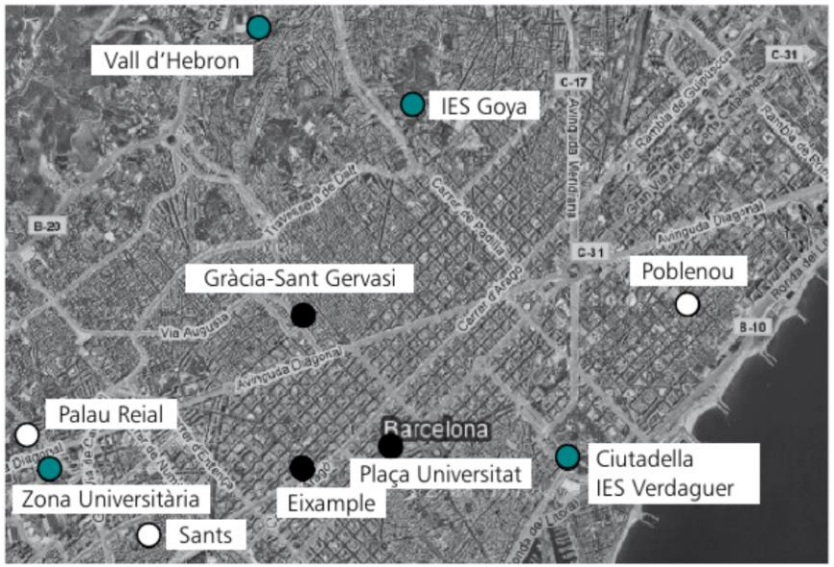
3. How accurate are output concentrations given by the developed system compared to CALIOPE-AQFS and monitoring station observations?

Methodologies

Source: Carlos Orti (2015)

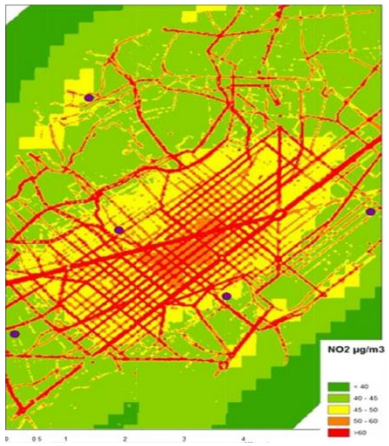
Scarce data for evaluation of the model

10 AQ monitoring stations available, 3 of them intense traffic stations and only 3 meteorological stations



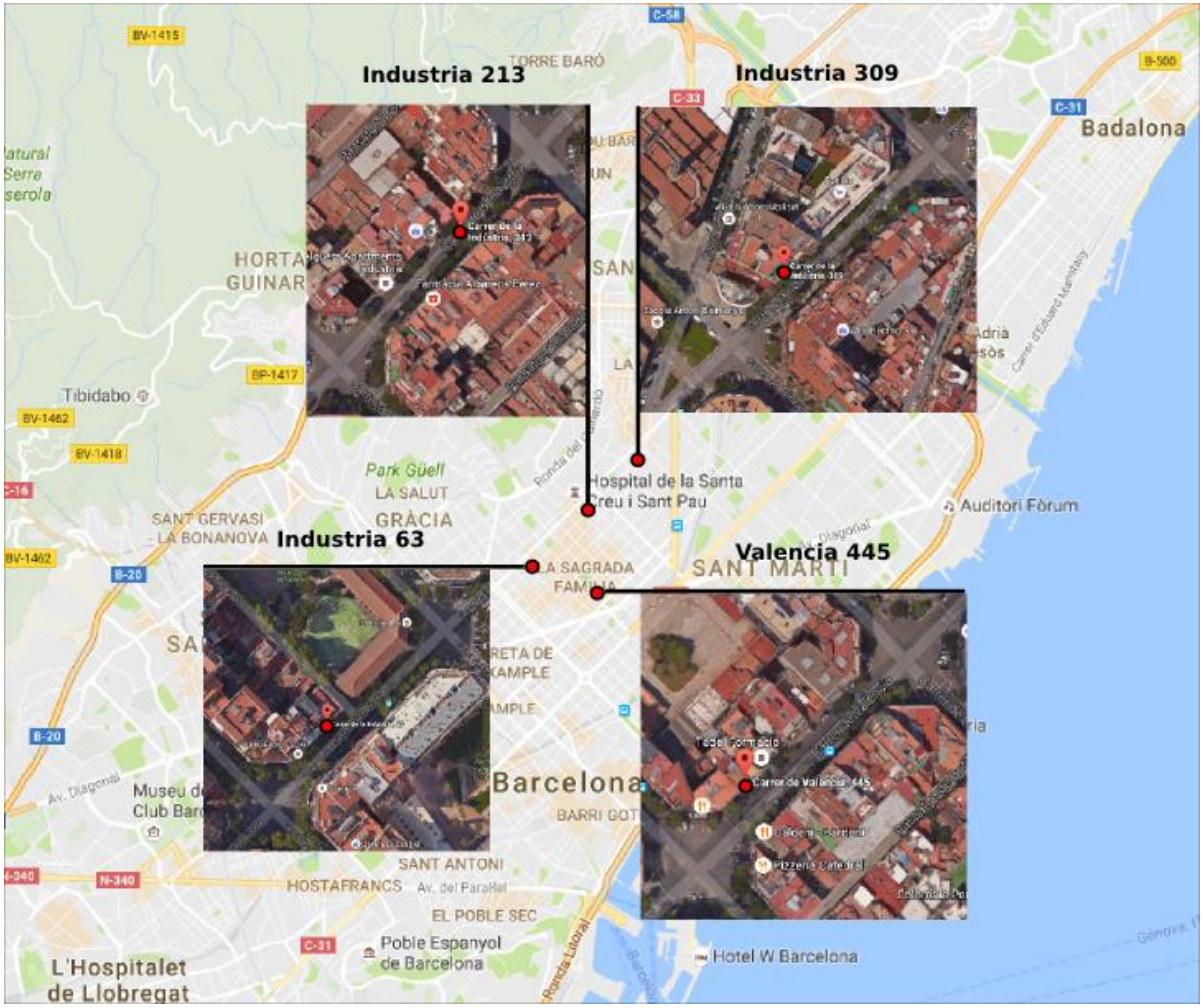
Exposure of general population and occurrence of higher concentrations

Not well represented



Duyzer et al. (2015)

Experimental campaign in April 2013



- Meteorological and air quality measures. Amato et al. (2014)
- April 2013 presents a 7-day air pollution episode

What street scale model?

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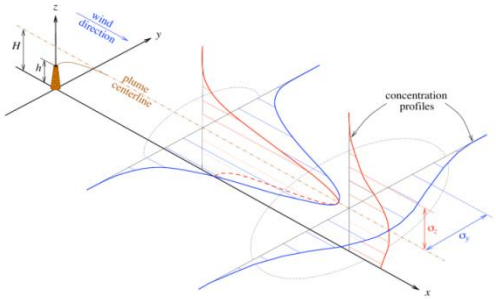
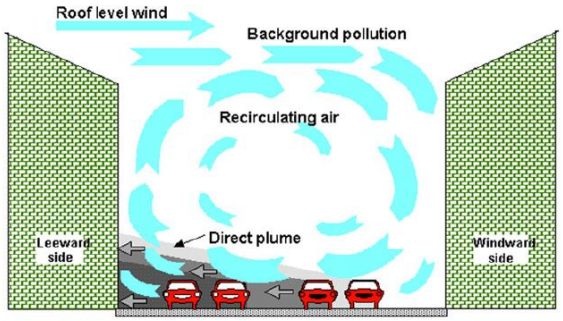
R-LINE
(Snyder et al., 2013)



Gaussian plume

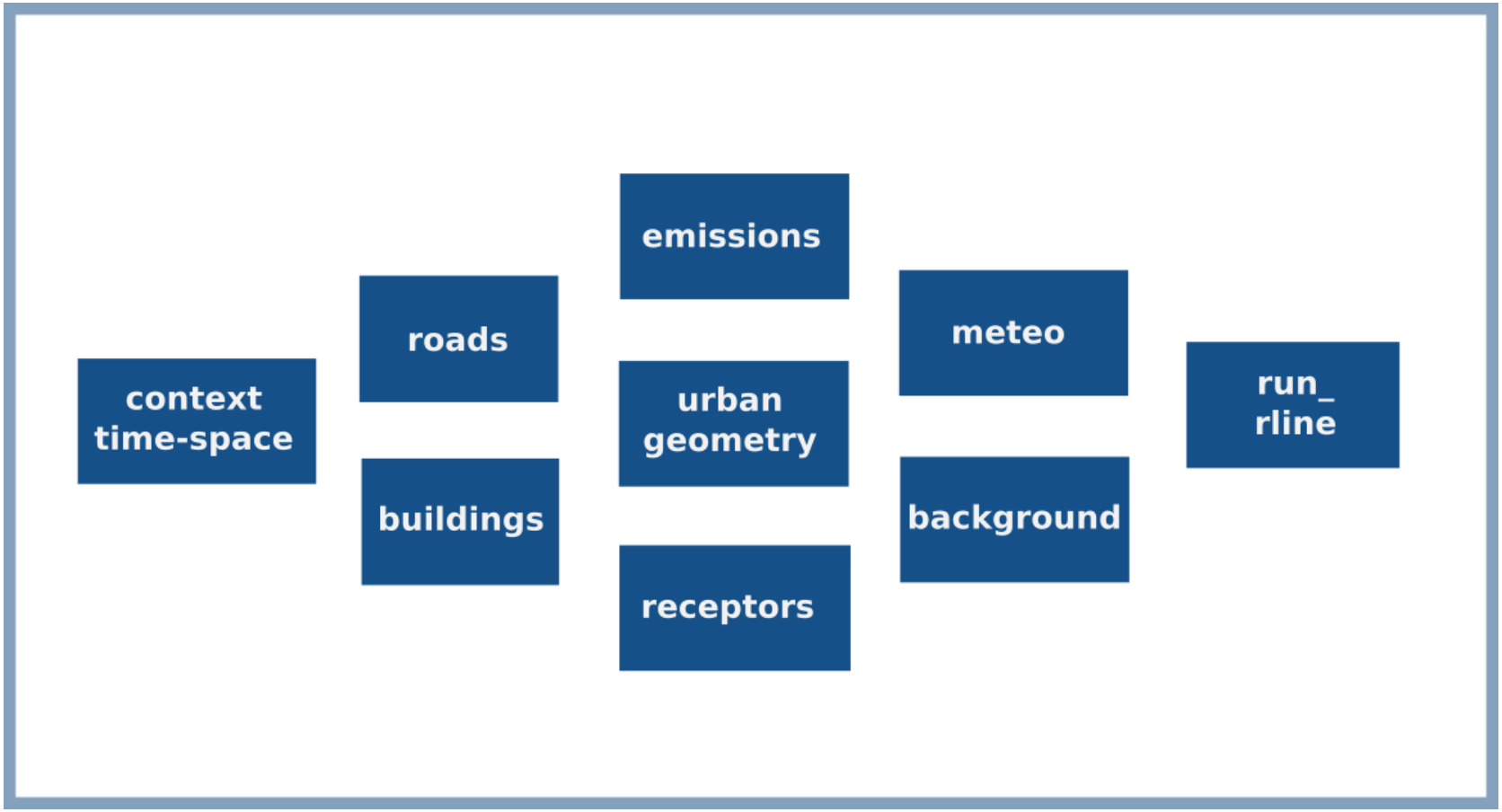
OSPM
(Berkowicz et al., 1997)



Street canyon

+	Line source dispersion and chemistry	+
−	Building-induced turbulence	+
+	Access to source code	−
+	Applied to whole cities	+
+	Combined with mesoscale AQMS	+

CALIOPE-Urban workflow



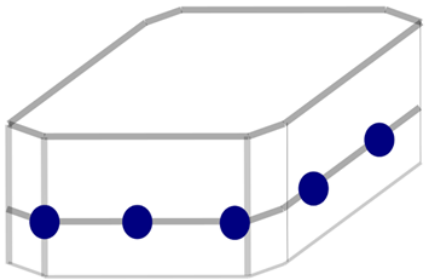
Urban geometry

Estimate building height to street width ratio, mean building height...

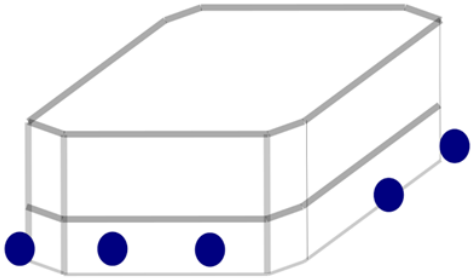
Receptors

3 options

Along building facades any distance in between



At any distance from building facades

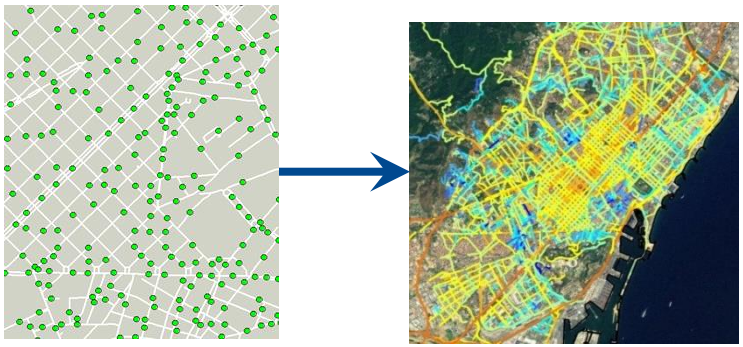


Specific coordinates

Emissions: HERMES model

Bottom-up emission model for Spain (resolution: 1x1 km^2 x1h)

Baldasano et al. (2008); Guevara et al. (2013)



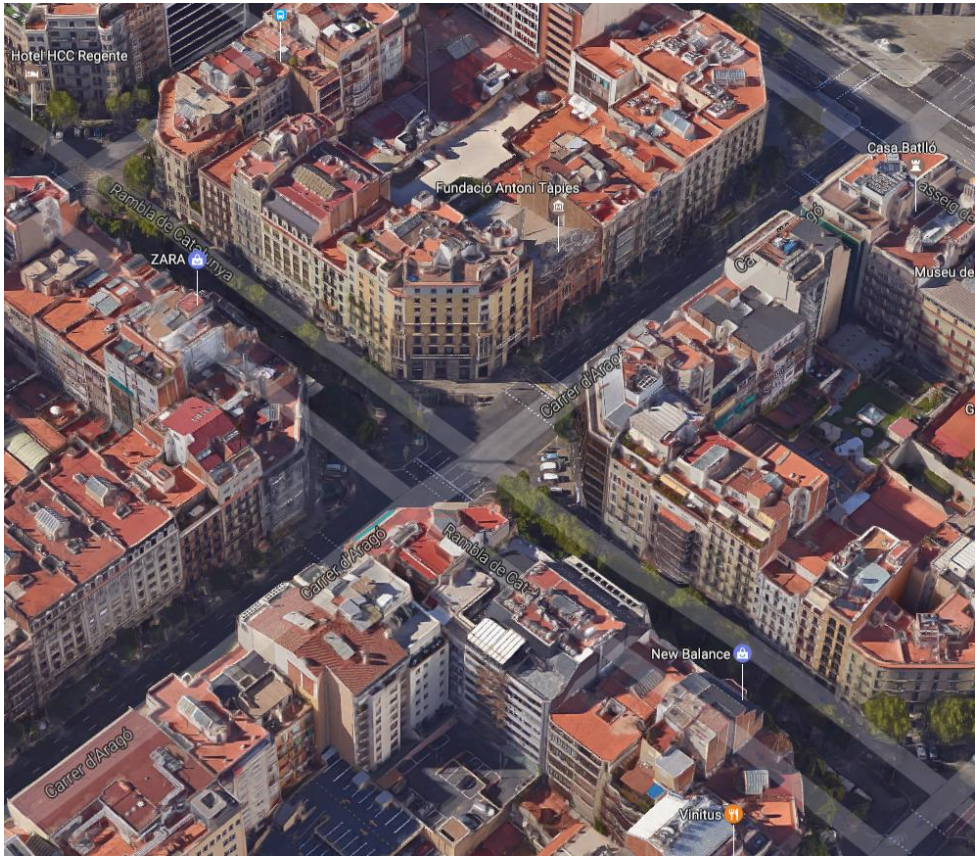
Road transport, emission estimation:

- COPERT → Exhaust emissions (hot&cold), evaporative emissions, tyre/break/road wear
- Resuspension (Pay et al., 2010)
- Updated for years 2011, 2012, 2013 and 2014

Meteorology: Adaptation of R-LINE to Barcelona

R-LINE world view
open terrain, one meteorological input

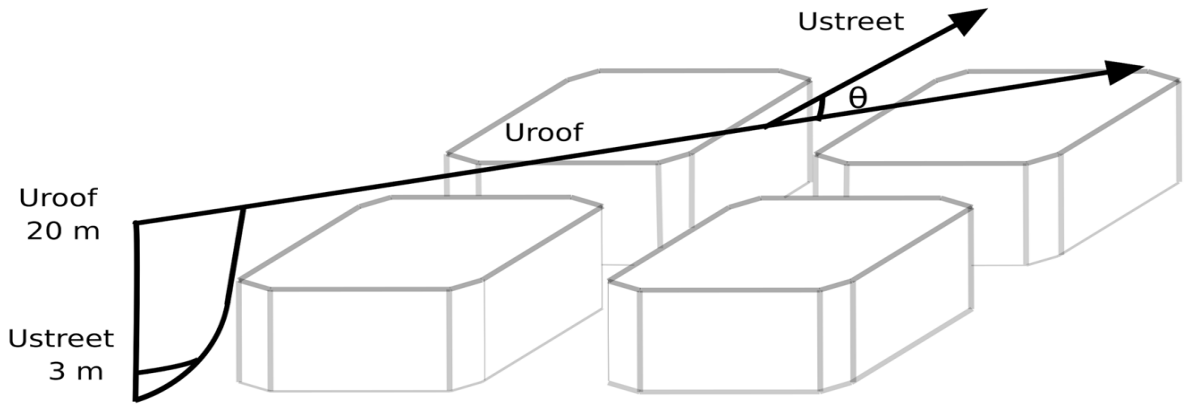
Barcelona reality
complex terrain, each street specific meteorological patterns



Meteorology: Adaptation of R-LINE to Barcelona

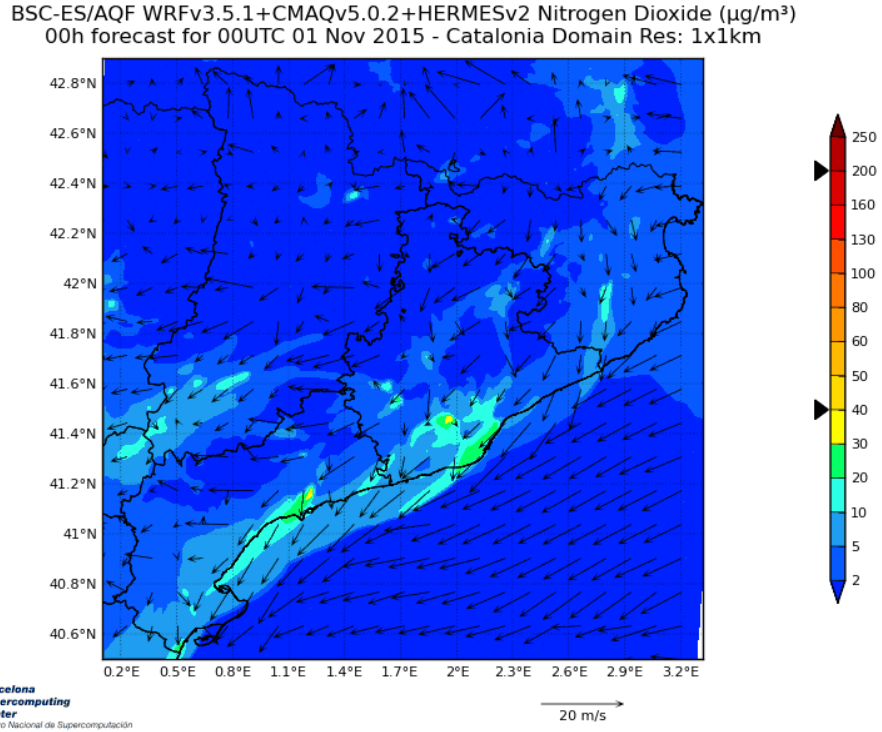
Adapt WRF wind to street level using RLINE (Snyder et al. 2013) local meteorology extension for each street segment:

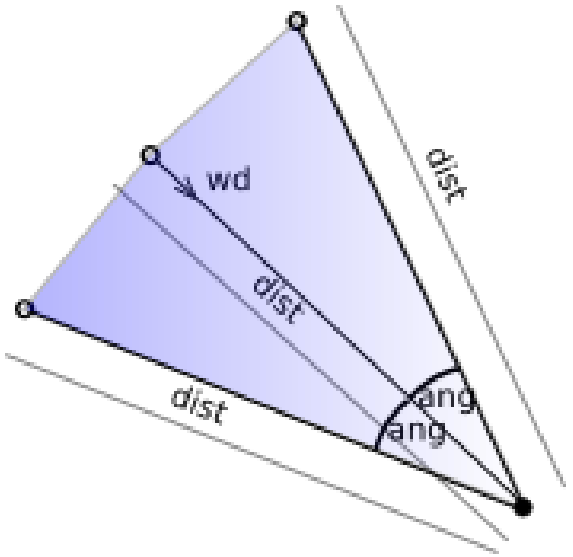
- Estimates local meteorological parameters (z0 and dh) using street geometry
- Re-calculates atmospheric stability parameters (ustar and Monin-Obukhov length)
- Adjust meteorology to obtain wind conditions



Spatially averaged velocity over street is function of cos(θ). Soulhac et al. (2008)

Background contributions: Triangle method





High spatial (1x1 km^2) and temporal resolution (1h) over Barcelona

Select concentrations from CMAQ depending on the wind speed and direction provided by WRF.

Results

Source: Carlos Orti (2015)

Periods with different meteorological conditions

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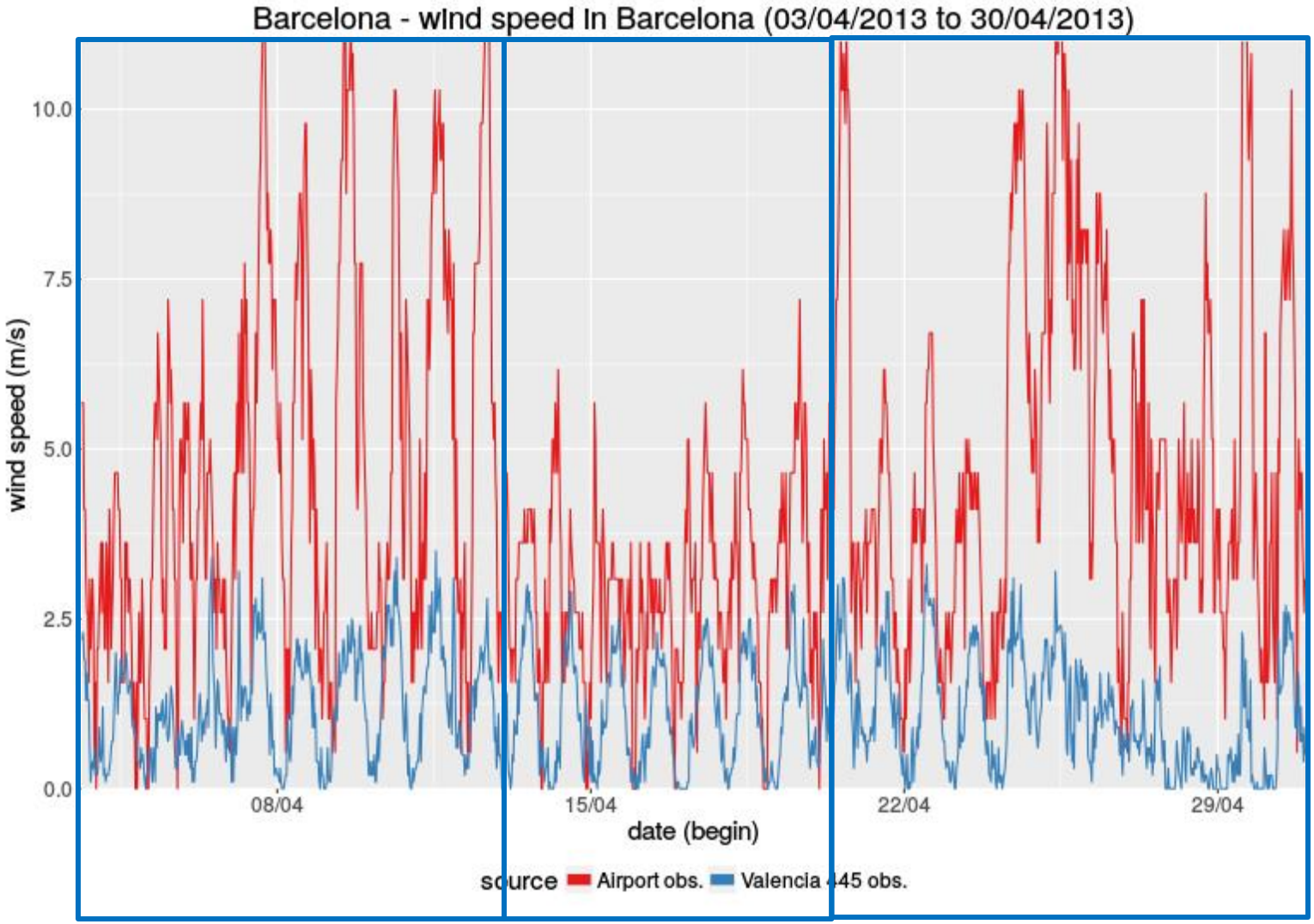

1-11 12-18 19-30

Meteorology: Wind channelled vs open terrain

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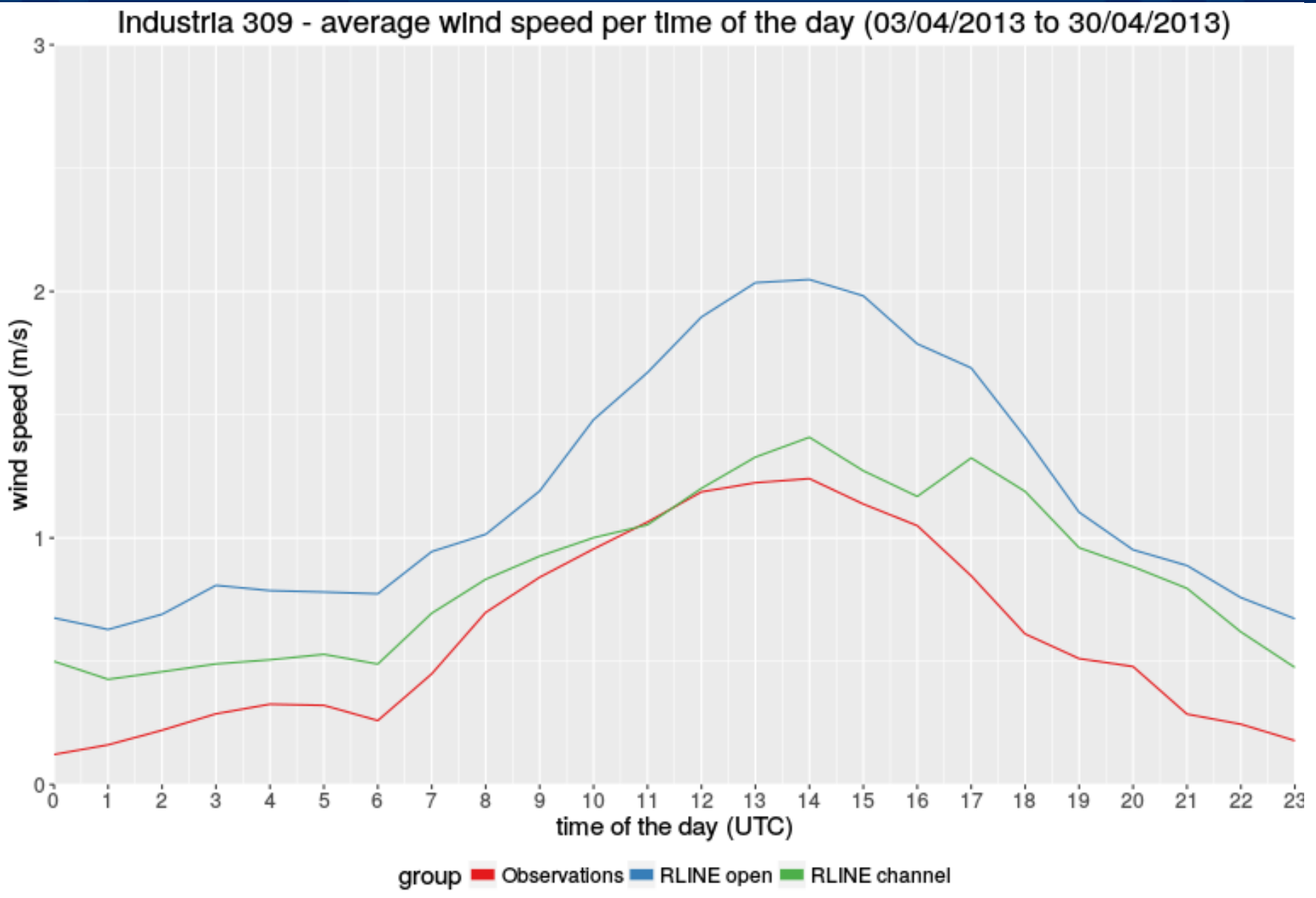
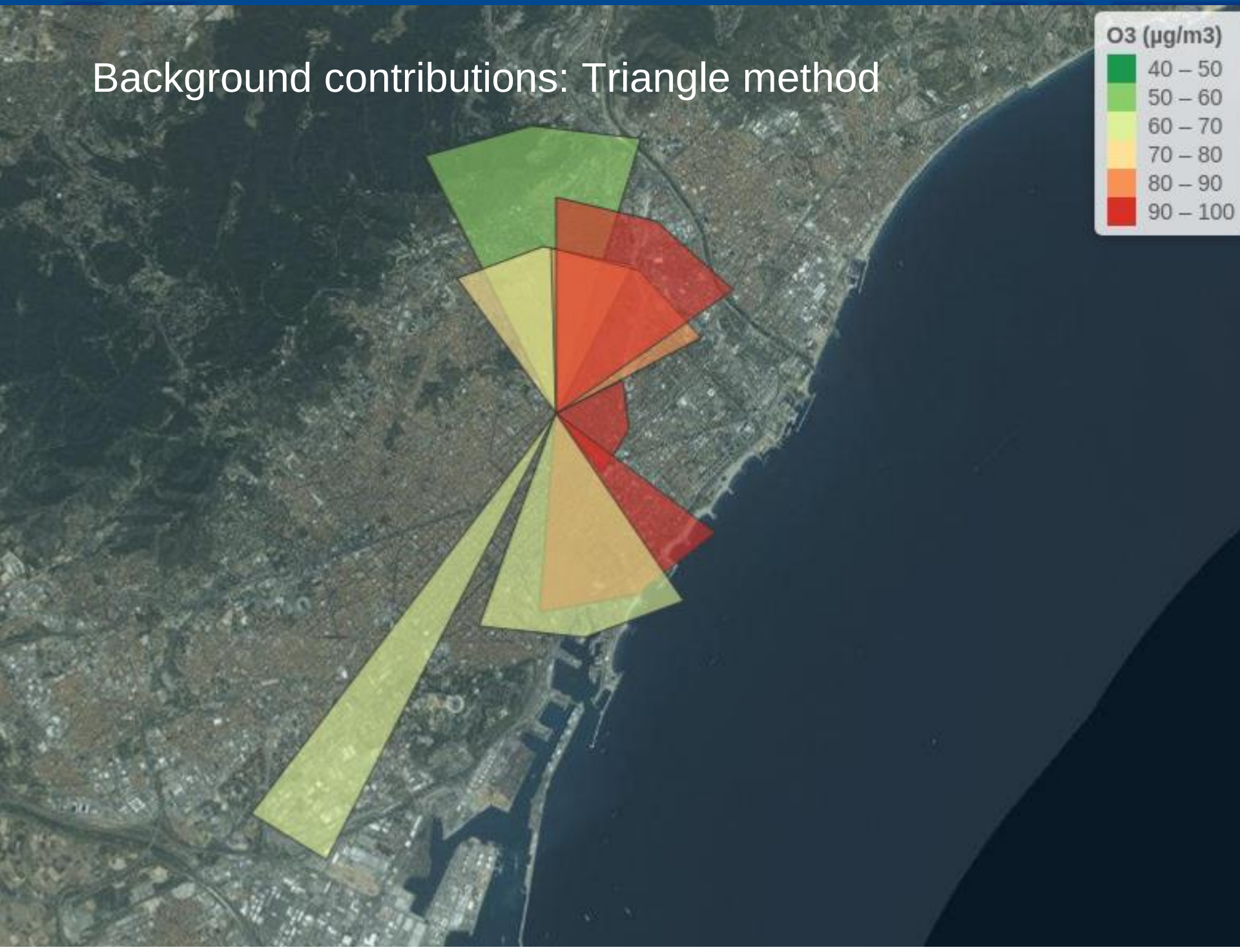


Background contributions: Triangle method



NO_2 Background concentrations

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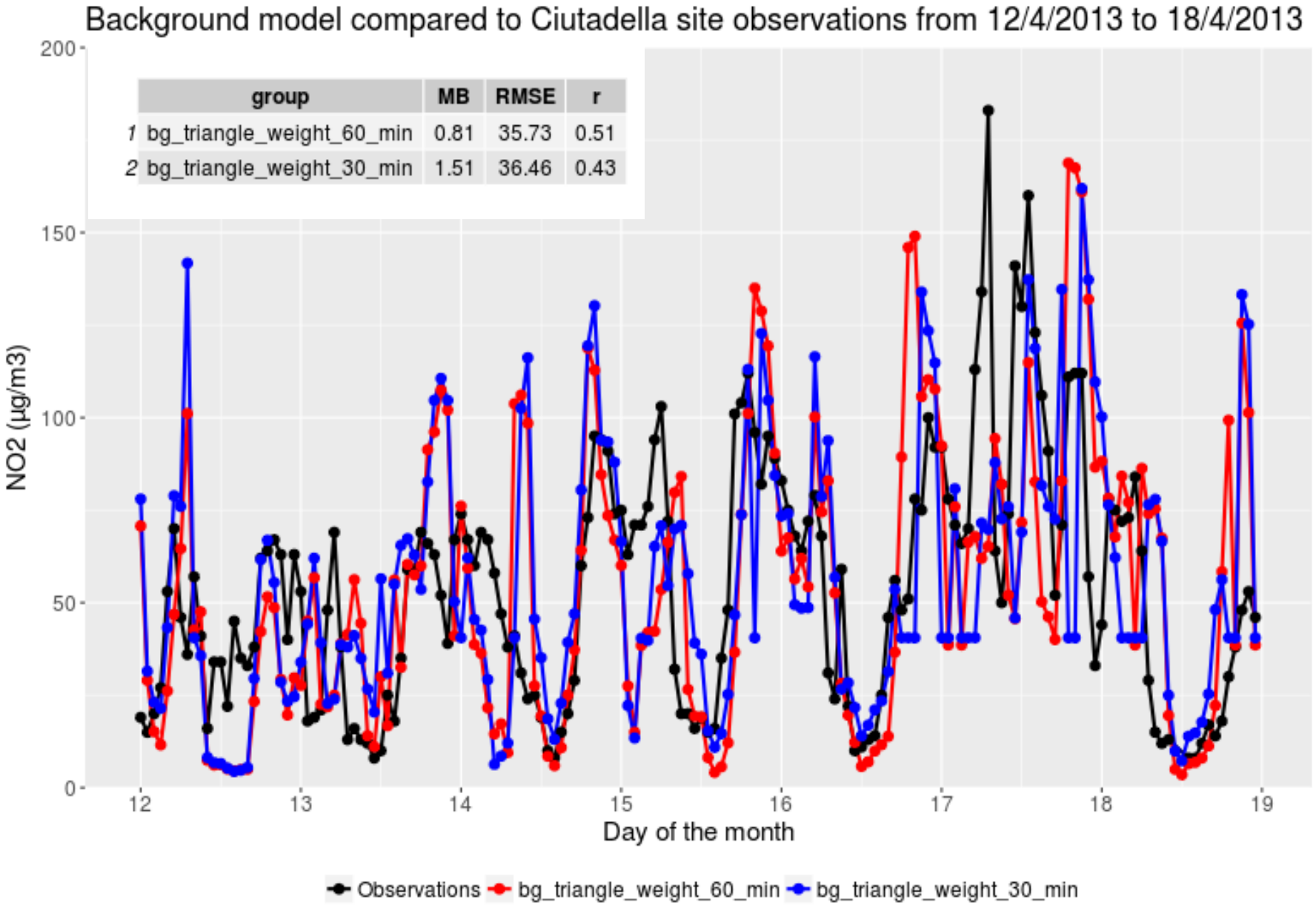

O_3 Background concentrations

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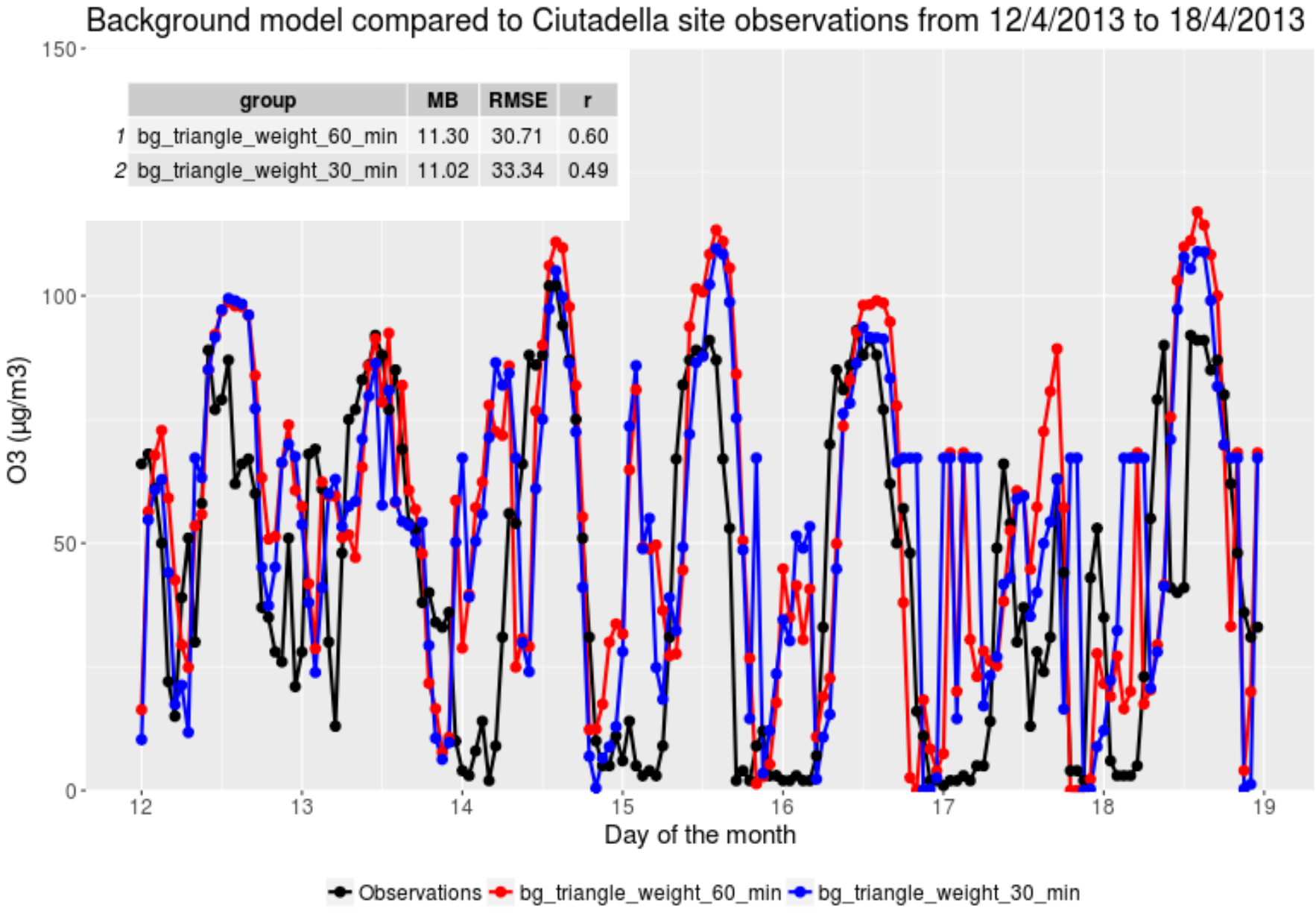
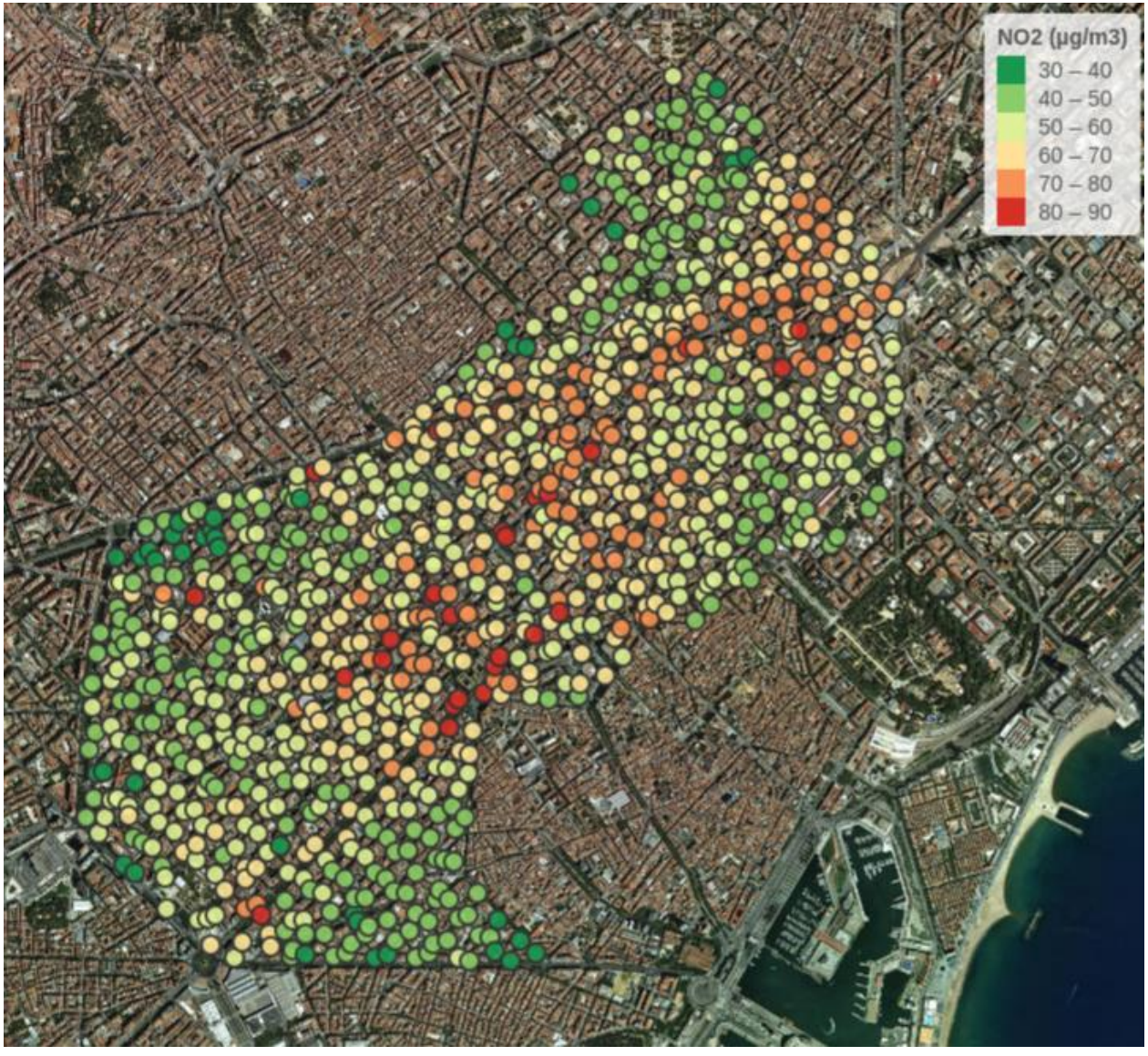


CALIOPE-Urban over Eixample District



CMAQ vs R-LINE NO_2 levels comparison

Period: April 2013

R-LINE configuration:

- local meteorology
- triangle background
- all emission sources in context
- executed over 1 km^2

Industria road 213 site

	group	MB	RMSE	r
1	rline	-5.98	34.94	0.47
2	cmaq	-24.79	39.39	0.45

Industria road 309 site

	group	MB	RMSE	r
1	rline	0.20	29.21	0.55
2	cmaq	-9.69	30.08	0.54

Valencia road 445 site

	group	MB	RMSE	r
1	rline	14.97	42.30	0.43
2	cmaq	-25.53	40.34	0.48

CMAQ vs R-LINE NO_2 levels comparison

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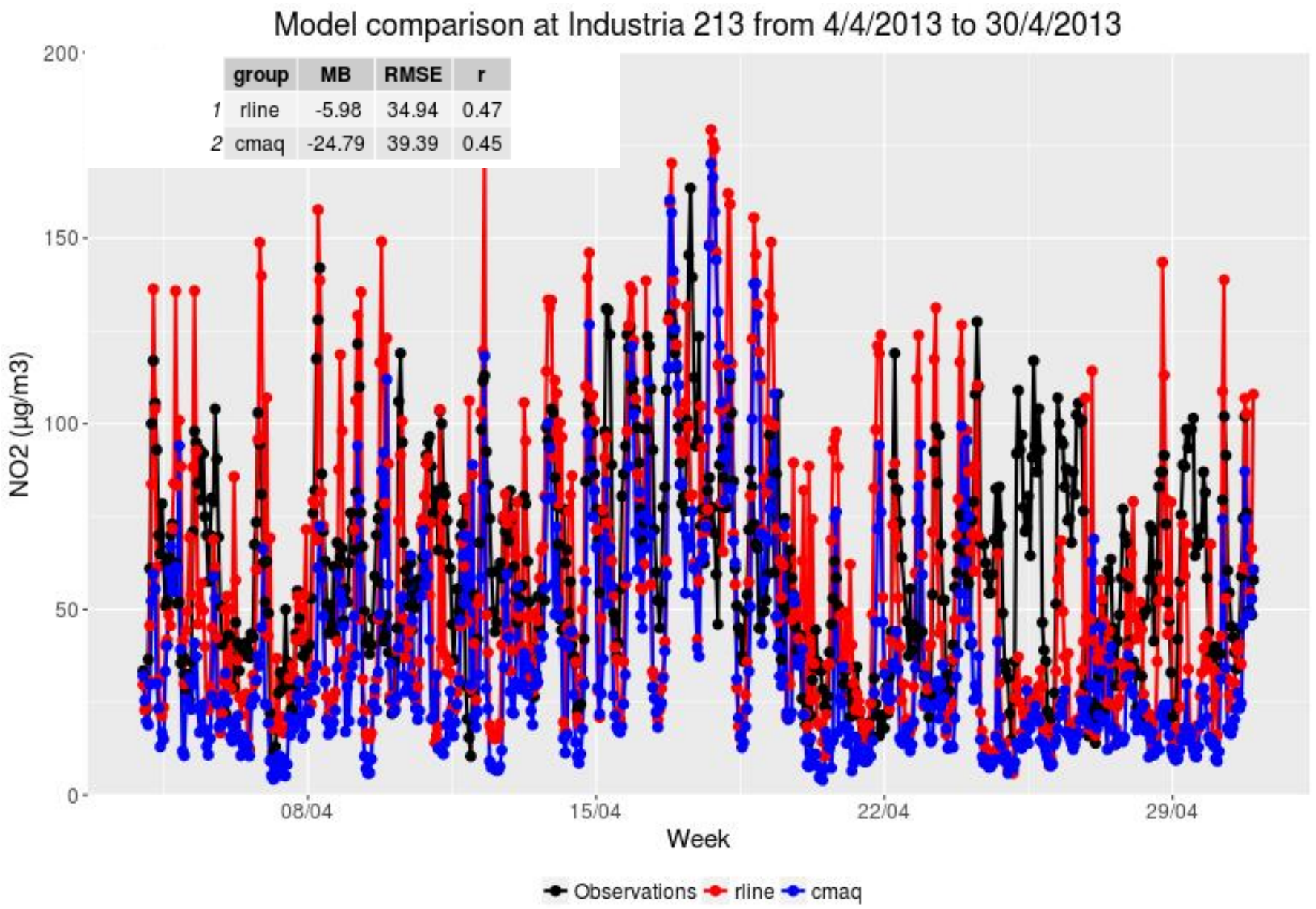
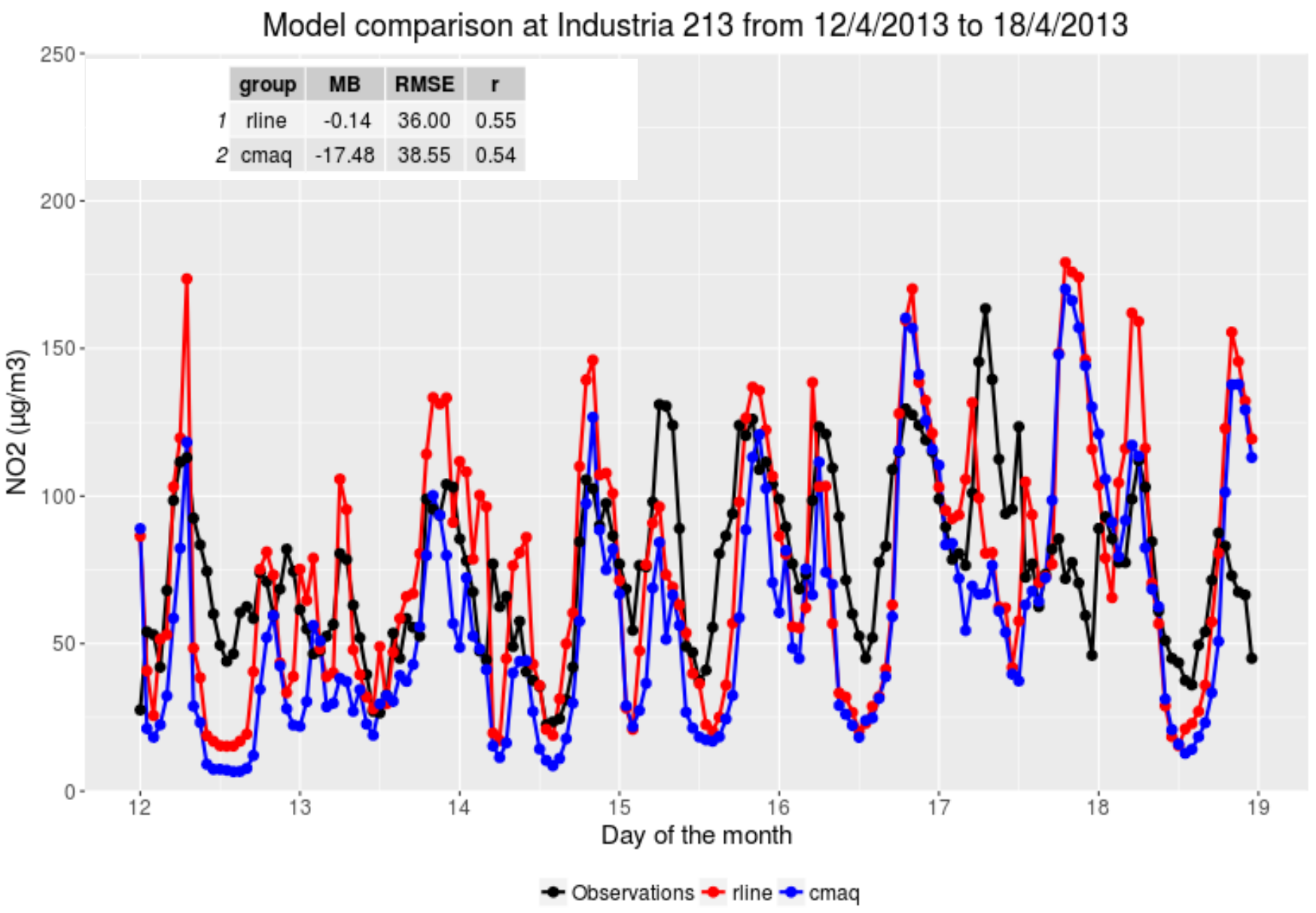


CMAQ vs R-LINE NO_2 levels comparison



Conclusions

Meteorology

- R-LINE extended to consider buildings when estimating street meteorological parameters

Background concentrations

- Triangle method developed to couple CMAQ with R-LINE:
  Avoids double-counting emissions
  Uses directly CMAQ outputs as input without re-executing CMAQ

CALIOPE-Urban

- Reproduces well diurnal pattern
- Morning and evening peaks well estimated in general but some days concentration too high
- Slightly improves CMAQ results in experimental campaign sites and provides a more detailed spatial pattern

Application: Political measure evaluation

Barcelona City Government (2017)

www.bsc.es

Thank you members of Institute for the Environment at UNC

for your

collaboration